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AERODYNAMICS OF E-BEAM SUSTAINED DISCHARGES IN FLOW(U)
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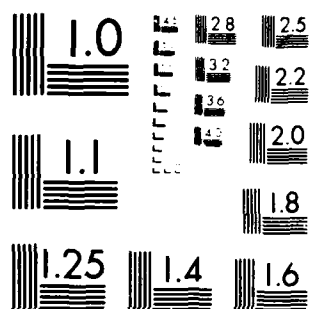
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Final Scientific Report
AFOSR Contract #82-0289
W.H. Christiansen

AERODYNAMICS OF E-BEAM SUSTAINED DISCHARGES IN FLOW

The fundamental mechanisms of the interaction of electric discharge of the glow type and the fluid mechanics normally found in electric discharge lasers has been studied.

BACKGROUND

High pressure, large volume glow discharges have become an important topic of study in recent years due to the development of high power electric lasers. The theoretical performance of laser systems using a combination of electric discharge and flow is very attractive, provided certain problems, not the least of which is the tendency of a glow to arc transition, are overcome. For cw or long pulse discharges this glow to arc transition undoubtedly is due in part to undesirable gas motion as a result of fluid mechanical interaction with the discharge. While there is considerable published material in the field of electric laser performance, little of it has been devoted to the basic interaction of flow and discharge physics in channels. We have studied the fundamental mechanisms between electrical discharges of the glow type and fluid mechanics as found in electric discharge lasers in an effort to improve the understanding of these devices.

Some basic information has already been obtained via small-scale experiments at the University of Washington, where a small-scale apparatus was built¹ to simulate an e-beam controlled discharge in flows. The flow and discharge characteristics are simulated using a combination of long duration pulsed flow and electric discharge. These small scale experiments accurately simulate much larger systems.

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Density measurements in the region of the cathode were extensively investigated and reported.² These measurements have clearly shown extensive cathode fall heating and the cathode shock wave. Of particular interest is the nonuniform density region near the cathode surface. This density field is probably due to heat diffusion phenomena, but it is orders of magnitude thick for the time scale of the study.² Nonuniform heating due to current spotting on the cathode is the likely cause, so more detailed observations were made. The development and growth rates of streamers above the cathode were observed and photographed. These streamers were shown to account for the excessively high "apparent" thermal diffusivity observed in the thermal layer above the cathode (1), and are believed to be the dominant mechanism for the "late" transition to arc (3). They may also account for the downstream pressure increase prior to transition to arc because of their adverse effect on the flow boundary layer.

Mechanisms for the formation of the streamers have been proposed. These are edge effects causing streamer formation; localized arcing near the cathode surface due to heating of the positive column by the cathode spots; and melting of the cathode surface by the cathode fall, leading to catastrophic bridging by the resulting molten material. The particular mechanism leading to streamer formation will depend on the discharge parameters, including the cathode surface condition. A qualitative understanding of the time for streamers to cross the discharge gap was also gained and modeled from the results of Ref. 4.

Pressure measurements are quite difficult to obtain in the noisy electrical environment. However, some pressure measurements have been taken both in a stationary gas and in a flow situation at $M = 3.2$. The measurements employ piezoelectric transducers, most of which were on hand and mounted near the main discharge cathode to detect the pressure rise due to volumetric heating by the discharge.

Theoretical and experimental methods were developed to demonstrate the feasibility and practicality of using pressure measurements to determine the effective one-dimensional power loading into the discharge, and the fraction of the discharge power going into gas heating (5). Observations were made of a substantial increase in the downstream pressure prior to a glow to arc transition, while the total discharge current remained constant.

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